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TROPICAL CYCLONE FORECAST VERIFICATION AS A FUNCTION OF RECONNA--ETC(U)
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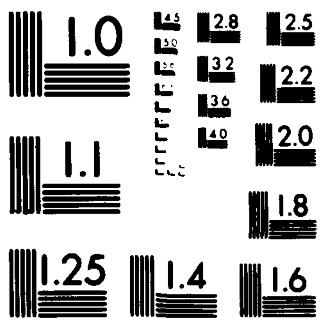

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Tropical Cyclone Forecast Verification as a Function of Reconnaissance Platform.

(9) by Technical note,

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Harrison (1975) examined tropical cyclone forecast accuracy as a function of the reconnaissance platform used as the basis for each forecast's initial position. Using 1973 and 1974 data, Harrison showed that forecasts based on aircraft position fixes were most accurate. This paper uses data collected from 1977-1979 to update Harrison's study. The present analysis shows that, overall, tropical cyclone initial positions and forecasts

based on aircraft positions fixes were most accurate when compared to tha Joint Typhoon Warning Center's best tracks. Unlike the earlier study, forecasts based on satellite reconnaissance were more accurate than forecasts based on aircraft reconnaissance for tropical cyclones which never reached typhoon intensity.

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TROPICAL CYCLONE FORECAST VERIFICATION AS A FUNCTION OF RECONNAISSANCE PLATFORM

I. INTRODUCTION

Accurate tropical cyclone warnings are critical to Department of Defense (DoD) operations in the western North Pacific Ocean. On the average, the western North Pacific can expect 32 tropical cyclones per year. This figure includes 18 typhoons and 10 tropical storms and is roughly three times the number of tropical cyclones that can be expected in the North Atlantic area. U. S. Naval Oceanography Command Center/Joint Typhoon Warning Center (JTWC) statistics compiled since 1971 show that the average absolute vector errors for 24-, 48-, and 72-hour forecasts are approximately 120 nm, 240 nm, and 360 nm, respectively (Figure 1). The DoD costs to take precautionary actions for tropical cyclones in the Atlantic area were discussed by Brand and Blellock (1975). They estimated that $12.9 million could be saved in the North Atlantic area with a 20-percent improvement in forecast accuracy. At present, costs in the western North Pacific area would be considerably larger than Brand and Blellock's estimates due to the higher frequency of tropical cyclone occurrences in this region and the high rate of inflation since 1974.

Figure 1 shows that the accuracy of tropical cyclone forecasts reached a plateau during the past decade. Without a major breakthrough in dynamic modelling, it is likely that only small, incremental improvements in forecast accuracy will be realized over the next decade. These improvements will result from the introduction of improved objective forecasting aids and a decrease in the positioning error of tropical cyclones.

This paper updates an earlier study by Harrison (1975) which examined tropical cyclone forecast accuracy as a function of the reconnaissance platform used to position the cyclone for each warning. Using 1973 and 1974 data, Harrison showed that forecasts based on aircraft position fixes were most accurate in comparison with satellite and radar position fixes. Results based on data collected from 1977 through 1979 only partially support Harrison's earlier findings. In the more recent data set, forecasts based on satellite reconnaissance were more accurate than forecasts based on aircraft reconnaissance for tropical cyclones that failed to reach 64 kt. Overall results for all tropical cyclones supported Harrison's earlier conclusions. Forecast procedures used at JTWC and data collection methodology are briefly reviewed before discussing results of the present analysis.

II. WARNING PROCEDURES

The actual surface location (position fix) of the tropical cyclone's eye or center just prior to warning time is extremely

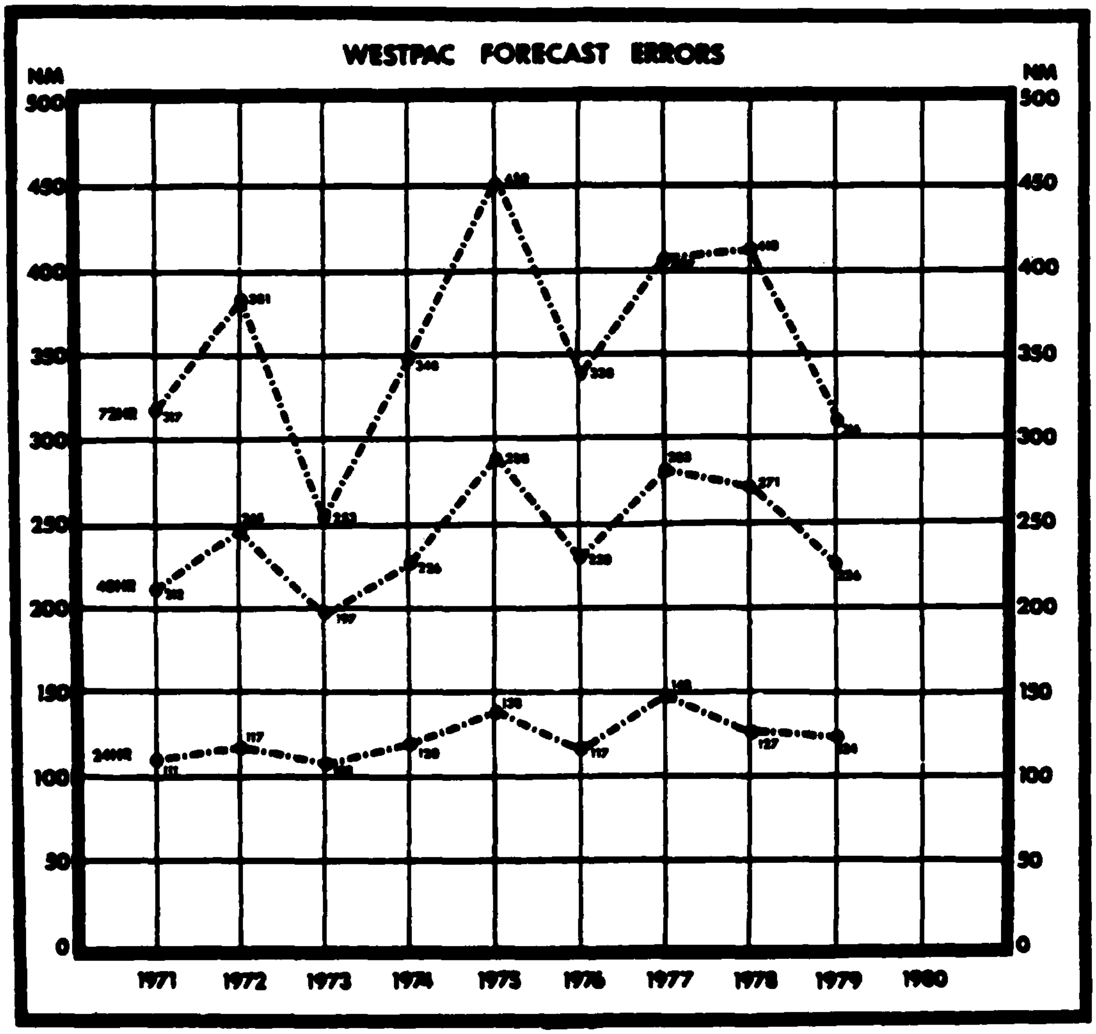

FIGURE 1. Annual vector errors (nm) for all tropical cyclones in the western North Pacific.

important in the preparation of each warning. A position fix valid between 2½-3½ hours before warning time allows the forecaster sufficient time to execute objective forecasting aids at the Fleet Numerical Oceanography Center, Monterey, California and to prepare the warning for transmission to field users. The "best estimate" of the surface location is subjectively determined from the analysis of all available data when conflicting information is received. The initial position at warning time is then determined by extrapolation using the current position fix and a "best track" of past cyclone movement. The initial warning position is, in effect, a short-range forecast 2½-3½ hours in length. Objective forecasting aids are then run using the initial warning position.

Each warning contains 12-, 24-, 48- and 72- hour forecasts of cyclone position. Short-range forecasts are heavily biased by extrapolation; whereas, longer-range forecasts are biased by the objective forecasting aids and climatology. The fix position based on aircraft, satellite, or radar data greatly influences the most recent segment of the "best track" which is used for the short-range extrapolation track. An error in the current fix position will feedback into the 12- and 24-hour official forecasts and, to a lesser extent, into the 48-hour forecast through an incorrect extrapolation track.

III. SELECTIVE RECONNAISSANCE PROGRAM

The Selective Reconnaissance Program (SRP) was developed to provide initial position data from aircraft, meteorological satellites, or land-based radar to support each tropical cyclone warning issued by JTWC. The selection of a platform for a specific warning is based on the tropical cyclone's location and intensity, the number of tropical cyclones, the timeliness of satellite coverage, and the availability of aircraft resources. Aircraft reconnaissance is provided by the 54th Weather Reconnaissance Squadron and Detachment 4 Headquarters Air Weather Service stationed at Andersen Air Force Base, Guam. Satellite reconnaissance is provided by the Western Pacific Satellite Surveillance Network. This network is coordinated by Det 1, 1WW, Nimitz Hill, Guam and also includes Det 5, 1WW, Clark Air Base, Philippines; Det 8, 30WS, Kadena Air Base, Japan; Det 15, 30WS, Osan Air Base, Korea; Det 4, 1WW, Hickam Air Force Base, Hawaii; and Air Force Global Weather Central, Offutt Air Force Base, Nebraska. Tropical cyclone positions based on land radar surveillance are passed to JTWC by military and civilian installations when well-developed tropical cyclones pass within radar range.

Application of the variable warning time option, which allows warnings to be issued ±2 hours around the standard synpotic times of 00, 06, 12 and 18Z, permits optimum use of meteorological satellites and aircraft reconnaissance in the tropical cyclone warning system. The ability to vary the warning time permits the Aerial Reconnaissance Weather Officer (ARWO) onboard reconnaissance aircraft to have sufficient daylight to observe the surface winds from the sea

state and to use satellite coverage which otherwise would be received too late to support a fixed warning time.

The SRP and application of the variable warning time have allowed JTWC to reduce its dependence on scarce aircraft resources. Since 1977, approximately 41 percent of all warnings were based on aircraft reconnaissance and 54 percent on satellite surveillance.

IV. DATA AND METHODOLOGY

Data from the years 1977-1979 were used for this study. A brief summary of verification procedures follows:

a. All tropical cyclone warnings were evaluated, including warnings with less than a 48-hour forecast length.

b. Warnings were segregated according to the reconnaissance platform used for the initial tropical cyclone position. Warnings that were based on more than one reconnaissance platform were deleted from the verification sample.

c. The initial, 24-hour, and 48-hour forecast position errors were extracted from verification data provided in the Annual Typhoon Reports (1977, 1978, and 1979). Verification data provided in these reports are derived by comparing each tropical cyclone warning against the best track for each cyclone. Each best track is constructed using a comprehensive post-analysis procedure based on all reconnaissance platform position fixes received at JTWC during the existence of the cyclone. Over the years, aircraft positions for tropical cyclone locations have been most accurate in comparison with other reconnaissance platforms. Radar and satellite position fixes for a cyclone with an eye have accuracies comparable to aircraft fixes. However, for less intense cyclones without any eye, radar and satellite position fixes are assumed by JTWC in the best-tracking process to be less accurate than aircraft position fixes. This assumption probably leads to an overemphasis on aircraft position fixes prior to eye formation in the best track process.

V. RESULTS

Forecast position errors for warnings based on aircraft, satellite, radar, and "other" are displayed in Tables 1 and 2. The "other" category includes warnings based on position fixes derived from extrapolation of past positions or from synoptic surface observations. Extrapolation and synoptic fixes were only used when a position fix based on a primary reconnaissance platform (aircraft, satellite, or radar) was not available prior to warning time. Satellite and aircraft reconnaissance support the largest percentage of warnings because radar reconnaissance is restricted to within approximately 200 nm of radar sites. These sites are situated on the periphery of the Asian mainland

TABLE 1

Forecast position error (nm) for various categories of reconnaissance platforms based on 1973 and 1974 data. Number of cases are show in parentheses. (Harrison, 1975)

a. All forecasts (tropical depressions, tropical storms and typhoons)

PLATFORM	FORECAST INTERVAL		
	INITIAL WARNING POSIT	24 HOUR	48 HOUR
Aircraft	18 (466)	111 (410)	207 (261)
DMSP Satellite	25 (358)	119 (248)	226 (126)
Radar	17 (61)	125 (36)	228 (22)
Other	43 (93)	151 (43)	---

b. Forecasts for typhoons (when maximum winds were 35 knots or more).

PLATFORM	FORECAST INTERVAL		
	INITIAL WARNING POSIT	24 HOUR	48 HOUR
Aircraft	16 (323)	106 (299)	200 (229)
DMSP Satellite	20 (205)	103 (162)	228 (111)
Radar	15 (39)	115 (26)	210 (20)
Other	36 (29)	122 (11)	---

c. Forecasts for tropical storms and tropical depressions.

PLATFORM	FORECAST INTERVAL		
	INITIAL WARNING POSIT	24 HOUR	48 HOUR
Aircraft	22 (133)	120 (95)	---
DMSP Satellite	32 (111)	146 (62)	---
Radar	21 (14)	152 (10)	---
Other	48 (53)	160 (30)	---

TABLE 2

Forecast position error (nm) for various categories of reconnaissance platforms based on 1977, 1978, and 1979 data. Number of cases are shown in parentheses.

a. All forecasts (tropical depressions, tropical storms and typhoons).

PLATFORM	FORECAST INTERVAL		
	INITIAL WARNING POSIT	24 HOUR	48 HOUR
Aircraft	17.6 (712)	124.0 (655)	251.8 (549)
DMSP Satellite	27.6 (841)	130.6 (694)	261.5 (506)
Radar	15.0 (51)	126.9 (43)	324.5 (28)
Other	60.2 (32)	159.3 (18)	271.4 (11)

b. Forecasts for typhoons (when maximum winds were 35 knots or more).

PLATFORM	FORECAST INTERVAL		
	INITIAL WARNING POSIT	24 HOUR	48 HOUR
Aircraft	15.2 (515)	116.5 (489)	247.7 (426)
DMSP Satellite	26.2 (552)	132.4 (470)	265.9 (377)
Radar	15.6 (26)	143.6 (25)	303.8 (16)
Other	78.9 (10)	177.2 (5)	203.5 (4)

c. Forecasts for tropical storms and tropical depressions.

PLATFORM	FORECAST INTERVAL		
	INITIAL WARNING POSIT	24 HOUR	48 HOUR
Aircraft	24.6 (155)	150.5 (126)	285.6 (83)
DMSP Satellite	29.4 (297)	149.7 (193)	267.0 (113)
Radar	14.5 (21)	108.7 (16)	317.1 (10)
Other	49.8 (21)	148.9 (13)	280.6 (7)

from Hong Kong and the Philippines northeast to Taiwan, the Ruykyu Islands, Korea, and Japan. For the period of this study (1977-79), satellite and aircraft reconnaissance supported 54 and 41 percent of all warnings, respectively. Radar and other reconnaissance supported the remaining five percent of the warnings.

Table 1 shows the results of the original study (Harrison, 1975). Forecasts based on satellite and aircraft reconnaissance for well-developed tropical cyclones (Table 1b) had comparable accuracy. For weaker cyclones (Table 1c), warnings based on aircraft reconnaissance were superior to warnings based on satellite reconnaissance.

Results from the 1977-79 tropical cyclone seasons are shown in Table 2. A noticeable difference between Tables 1 and 2 is the overall increase in absolute vector error for the 24- and 48-hour forecasts between the earlier and present studies. This, of course, is a reflection of JTWC's forecast performance for the periods included in the two studies. The relationship of the accuracy for the initial warning positions remained unchanged. That is, initial positions based on aircraft and radar reconnaissance were more accurate than initial positions based on satellite reconnaissance. A comparison between Tables 1 and 2 also shows two interesting changes in the accuracy of warnings based on aircraft and satellite reconnaissance. In the later study, a clear distinction exists between aircraft and satellite for typhoons when maximum winds exceeded 35 kt (Table 2b). On the other hand, warnings based on satellite data for tropical cyclones which failed to intensify (Table 2c) are slightly more accurate than warnings based on aircraft data. The explanation for this reversal from the earlier study is not known. Larger forecast errors associated with radar reconnaissance cases are due to the fact that cyclones in this small sample were already in the recurvature portion of their tracks when within range of land-based radar.

VI. SUMMARY

Table 2 shows that aircraft and radar reconnaissance platforms provide more accurate initial positions for tropical cyclones than satellite or other platforms. For all tropical cyclones, warnings based on aircraft reconnaissance were slightly more accurate than warnings based on satellite reconnaissance. These results were expected and were also found by Harrison (1975). The significant difference of this study in comparison with Harrison is the fact that warnings based on satellite position fixes were more accurate than warnings based on aircraft position fixes for tropical cyclones that did not develop to typhoon intensity. The explanation for this result is not clear.

As a result of the latter finding and as supported by Shewchuk and Weir (1980), it is evident that satellite reconnaissance has a

gnificant role in the positioning and forecasting of tropical clones. The effectiveness of satellite reconnaissance has been monstrated for positioning, for estimating and forecasting maxim wind intensity (Shewchuk and Weir, 1980), and, particularly, r detecting the early development of tropical disturbances into opical cyclones.

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